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Agricultural uses of alkaline fluidized bed combustion ash: case studies

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Successful programmes were developed by Ahlstrom Development Ash Corporation and Air Products and Chemicals for using fluidized bed combustion ash as a substitute for agricultural lime on dairy farms in northern New York state and on fruit and nut crops in the San Joaquin Valley of California. The companies developed these programmes by utilizing the methodology developed through USDA-ARS research and working closely with agricultural consultants and regulatory agencies to ensure that the ash applications were both agronomically and environmentally sound. *Published by Elsevier Science Ltd.*

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To conform to US EPA standards, electric generating plants that burn coal must adopt effective methods for removing SO_2 from the exhaust gas. One such method is the fluidized bed combustion process, in which crushed coal and finely ground calcitic or dolomitic limestone are suspended or 'fluidized' by jets of air and burnt at a controlled rate and optimum temperature of 850–900°C. The SO_2 produced from the coal reacts with the Ca^{2+} or Mg^{2+} from the limestone and O_2 to form $CaSO_4$ or $MgSO_4$. The resulting ash typically contains significant amounts of $CaSO_4$ or $MgSO_4$ and CaO or MgO. All four of these compounds have potential to be used as soil amendments to improve structure, increase pH or reduce the toxicity of aluminium, provided that trace and toxic metals are within acceptable limits.

Since 1976, the Agricultural Research Service (ARS) of the United States Department of Agriculture (USDA), with support from the United States Department of Energy (DOE), has been involved in developing the use of atmospheric fluidized bed combustion (AFBC) ash as a substitute for agricultural lime. Protection of the food chain and documentation of the beneficial use of AFBC ash have been the primary concerns throughout this development effort.

The technology transfer part of the development process began with the publication of a manual for applying AFBC ash to agricultural land in 1988[1]. Two of the companies which have cooperated closely with ARS—Ahlstrom Development Ash Corporation and Air Products and Chemicals—have developed ash spreading programmes in New York State and California. This paper presents some experiences of these two companies in developing successful application programmes.

AHLSTROM DEVELOPMENT ASH CORPORATION: WATERTOWN, NY

The Fort Drum HTW cogeneration plant is located at Fort Drum near Watertown, New York State. This plant uses three Ahlstrom Pyroflow® fluidized bed boilers to produce high-temperature and pressure steam for electricity generation and hot water for heating. The power plant uses anthracite and bituminous coal as well as clean wood chips for fuel. A locally quarried limestone is injected into the furnace as the reactant. The plant annually produces some 40 000 tonnes of ash.

The plant was commissioned in 1989. The original plan for ash disposal was to use the local landfill. However, disposal costs were very high, and the local landfill was rapidly running out of space. The area around Fort Drum is principally agricultural, with dairy operations prevailing. Discussions with the local agricultural experts indicated that limestone ($CaCO_3$) was being used sparingly by farmers, due to its relatively high cost and the marginal economic nature of their farms. Because the Fort Drum ash had a relatively high $CaCO_3$ equivalence (CCE) due to unutilized CaO as well as small amounts of essential plant nutrients, it was decided that an agricultural application programme

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should be developed, based on the work published by the USDA-ARS[1].

The development of an agricultural application programme required Ahlstrom to investigate governmental permits, development of spreading equipment and market development. Thomas L. Nickeson, Consulting Geologist, was employed to assist in the development of the application programme.

The New York State Department of Environmental Conservation (DEC) regulates solid wastes, which include ash. The state regulations provide case-specific Beneficial Use Determination (BUD) permits for using regulated wastes, upon demonstration that:

- the proposed use of the material constitutes a reuse rather than disposal;
- the material is intended to function or serve as an effective substitute for an analogous raw material;
- the material must have an existing market or it is reasonably certain to be developed; and
- the proposal must be consistent with the solid waste management policy, which sets standards for potentially toxic metals.

The above requirements were addressed in a petition to the New York DEC for a BUD in which ash solids and leachates were extensively characterized. The DEC specified that the leachate data would be based on Toxic Characteristic Leaching Procedure (TCLP) protocols. The petition also demonstrated that the proposed application rates would not be harmful to soils or plants. The USDA-ARS publication[1] was used extensively as a reference and data source. After several additional data requests to clarify the information, the DEC issued a BUD in 1992. In addition to securing a BUD, the ash was registered with the New York Department of Agricultural Markets as a liming agent having a minimum CCE of 60%.

Two options were available for ash application: wet or dry. In view of the cementitious nature of the ash, it was feared that the material could not be spread if mixed with water. A drop spreader was selected, based on an investigation of lime spreading equipment. The drop spreader was chosen in preference to rotating disk spreaders, to minimize the fugitive dust associated with the ash application. In 1993, Ahlstrom Development Ash Corporation purchased a drop spreader mounted on a custom Peterbuilt cab and chassis. A customized conventional truck chassis was selected to permit road movement of the application equipment while providing the ability to move within fields with minimal damage.

To transport ash from the power plant to farm fields, two contractors were selected who each provided a pressure differential trailer and a truck tractor unit equipped with a pressure blower which allowed the ash to be unloaded at any field location. With the use of these two units, it was possible to keep the drop spreader truck in the field, except when transferring ash. A nominal 20 tonne load of ash can be transferred from the truck trailer unit to the drop spreader truck in ~50 min and spread in ~15 min.

To develop a market for the ash, several steps were taken. First, a brochure describing the ash material and benefits of use was prepared. This was distributed at the local county fair and in person on farm-to-farm calls. Second, advertisements were placed in the local newspapers and agricultural magazines. The county agricultural extension agent was provided with a copy of the research report[1] on the benefits of the use of ash so that he could assist in answering questions from farmers. Lastly, the ash was initially provided and spread in the field at no cost to the farmer. At the end of the first year, a total of 13 400 tonnes of ash had been spread. In 1994, the quantity increased to 28 320 tonnes, > 71% of the ash produced by the plant.

In late 1993, to keep up with the demand from farmers for the ash, wet spreading was attempted. The plant was built with an ash conditioner that adds water (~23 wt% db) to the ash in the storage silo and mixes the ash before discharge to a truck. The addition of the water immediately hydrates the CaO and $CaSO_4$, resulting in the release of heat and steam which reduces the effectiveness of water addition for dust control. The conditioned ash was trucked from the plant to a farm field in a covered dump truck, dumped in a pile, with additional water added if needed, and reloaded into a rotating-plate spreader using a front-end loader. This handling broke up large lumps that might have formed before loading into the spreader. No problems were experienced with ash solidifying in the spreader.

The agricultural application programme is a successful and integral part of the ash management strategy for the Fort Drum plant. The use of the programme and other beneficial uses has reduced ash disposal costs for the plant from $55.65 per tonne in 1990 to an estimated $18.47 for 1995. In addition, local farmers saved over $300 000 in limestone purchases during the first two years of the spreading.

AIR PRODUCTS AND CHEMICALS: STOCKTON, CA

Air Products and Chemicals, Inc. operates a coal-fired cogeneration unit at 1010 Zephyr Street, Stockton, CA. The Stockton facility consists of a single 180 MW circulating fluidized bed (CFB) boiler unit which fires annually ~210 000 tonnes of low-sulfur bituminous coal. As a by-product of combustion, the facility produces annually ~22 200 tonnes of CFB ash.

The CFB ash by-product produced by the power plant is rich in CaO and $CaSO_4$ as a consequence of injection of limestone into the boiler for SO_2 control. Because of mixing and timing constraints, to maintain continuous compliance with the operating permit limits, limestone is injected in excess of that theoretically needed. As a result, unutilized CaO and MgO is produced as well as $CaSO_4$, and is captured in the baghouse together with the gypsum and coal ash. Typically, the ash from the Stockton facility contains ~66 wt% coal ash, 20 wt% $CaSO_4$ and 14 wt% unutilized lime (CaO, MgO).

Exploration of the possible use of this ash as an agricultural soil amendment began in 1989. Before this ash could be considered for agricultural use, it was necessary to show that it was both agriculturally beneficial and environmentally safe. The California Regional Water Quality Control Board (RWQCB) provided environmental oversight. Triad Energy Resources, Inc., agricultural consultants to California growers throughout the San Joaquin Valley, provided agricultural evaluation.

The metals content of the ash was found to be below both the federal (TCLP) and California soluble threshold limit concentration (STLC) and total threshold limit concentration (TTLC) standards. In addition, it was below that typically found in treated municipal sewage sludge, and was comparable with that of background soils from the central San Joaquin Valley and the more traditional agricultural soil amendment products. The most significant agricultural property of this ash is its liming capacity, which can be

used to raise the pH of the naturally acidic eastern San Joaquin Valley soils to the desired range of 6.5–7.0.

It having been shown that the ash could be used in an agriculturally beneficial and environmentally safe manner, the proposed application programme was approved by the RWQCB. Each prospective application site was evaluated in terms of chemical need, soil character, proximity to surface water, depth to ground water and surrounding land use. As each site was approved, the background metal concentrations in soil and plant tissue were determined. The application rate for a site was based on the site's lime need and metals content of the ash. Each calendar quarter, the ash is analysed to determine the total metal loadings for each approved site. These metal loadings are compared with the annual and lifetime limitations established by the US EPA under Title 40 CFR Part 503. Each year, soil and plant tissue testing is conducted to verify the metal loading evaluation. Before any site receives an ash application, testing must demonstrate a clear agronomic need. All records of quarterly ash analyses, shipment tonnage and destination are kept on file with quarterly and annual reports submitted to the RWQCB. These reports provide ash analyses together with a summary of the tonnage applied at each site, the total metals loadings by site, and plant tissue and soil analyses. From 1991 to 1994, $>$ 27 000 tonnes of CFB ash were applied to crops such as melons and almonds on 16 sites, covering $>$ 5250 ha in the San Joaquin Valley.

DISCLAIMER

Mention of a trade name does not imply endorsement by the US Department of Agriculture.

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